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Soil Stabilization – A Comprehensive Review

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ABSTRACT: Soil stabilization is an essential geotechnical technique used to improve the engineering properties of weak soils for construction purposes. Poor soil conditions such as low bearing capacity, high compressibility, and excessive swelling pose serious challenges in infrastructure development. Stabilization techniques involve mechanical, chemical, and advanced methods to enhance soil strength, durability, and performance. This paper presents a comprehensive review of soil stabilization methods, materials used, influencing factors, and their applications in civil engineering. The study highlights the importance of selecting appropriate stabilization techniques based on soil type, environmental conditions, and project requirements. Modern trends such as the use of waste materials, fibers, and eco-friendly stabilizers are also discussed.

I. INTRODUCTION

Soil is one of the most fundamental materials used in construction. However, not all natural soils possess adequate engineering properties required for construction activities such as highways, foundations, embankments, and retaining structures. Weak soils, particularly clayey and silty soils, exhibit low bearing capacity, high compressibility, and significant volume changes due to moisture variation. These characteristics can lead to structural failures if not properly treated. Soil stabilization is the process of improving soil properties such as strength, stiffness, and durability to make it suitable for construction purposes. This is achieved by mechanical means, chemical additives, or a combination of both. Stabilization not only enhances the load-bearing capacity of soil but also reduces permeability, plasticity, and swelling behavior. In recent years, there has been a growing emphasis on sustainable construction practices. As a result, researchers have explored the use of industrial by-products such as fly ash, rice husk ash, and quarry dust in soil stabilization. These materials not only improve soil properties but also help in waste management and environmental protection.

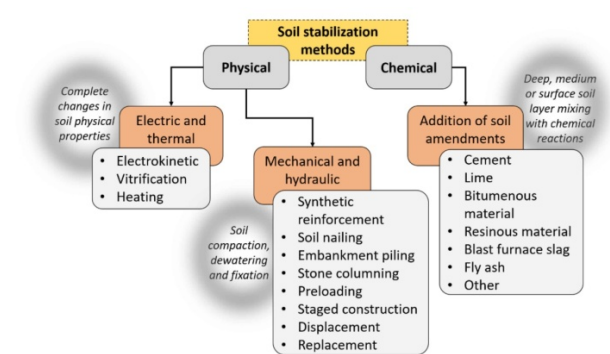
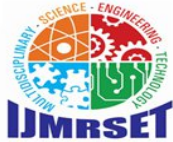


Figure 1: Flow Diagram of Soil Stabilization Methods

II. LITERATURE REVIEW

Soil stabilization has been widely studied in geotechnical engineering to improve the strength, durability, and load-bearing capacity of weak soils. Various researchers have explored mechanical, chemical, and sustainable stabilization methods.

Duke Magara, Haicheng She systematic review of soil stabilization techniques focusing on lime, cement, and fly ash. The study follows the PRISMA methodology and analyzes research published between 2013–2023.



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Relevance to current Research

Shahzada Omer Manzoor, Aadil Yousuf use of lime as an effective soil stabilizing agent (2020) , This paper presents a comprehensive review of the use of lime as an effective soil stabilizing agent, particularly for fine-grained soil

Relevance to current Research

The proposed method for performing the digital forensic observation in Cloud on VM for introspection which addressed the issues related with the assembling of evidences. For resolving they made use of certain methods of introspection on VM.

Relevance to current Research

This paper presents a comprehensive review of different soil stabilization techniques using materials such as cement, lime, fly ash, rice husk ash, and geofoam.

Relevance to current Research

This research work was carried out by Anurag, Aman Bathla, and Dr. Gurcharan Singh, who are researchers in the field of civil and geotechnical engineering, focusing on soil improvement techniques for construction applications.

Relevance to current Research

This research investigates the stabilization of subgrade soil using lime, cement, and Plaster of Paris (POP). Laboratory tests such as Maximum Dry Density (MDD), Optimum Moisture Content (OMC), and California Bearing Ratio (CBR)

No.	Paper Title	Author Name	Key Points	Remark
1	systematic review of soil stabilization techniques	Duke Magara, Haicheng She (2024)	1)Reviewed lime, cement, and fly ash stabilization 2)Used PRISMA 3)Cement → high early strength 4)Lime → reduces plasticity in clay	This paper provides a clear comparative analysis of traditional stabilizers and is useful for material selection in projects.
2	Stabilisation of Soils with Lime	Shahzada Omer Manzoor, Aadil Yousuf (2020)	Lime reduces plasticity; works best for clay; involves pozzolanic reactions	Best for expansive soils; economical and widely used
3	Stabilization of Soil	Santosh Dhakar, S.K. Jain (2016)	Reviewed cement, lime, fly ash, waste materials; improves bearing capacity	Focus on sustainable materials; slightly outdated but useful basics
4	Study on Soil Stabilization Using Lime and Cement	Anurag, Aman Bathla, Dr. Gurcharan Singh (2020)	Lab tests (CBR, MDD, OMC); combined stabilizers give better results	Practical experimental study; useful for design approach
5	Geopolymer-Based Soil Stabilization Using Waste Materials	Mohammed Riyadh Hayder, Hassan Ziari, Alaa M. Shaban (2025)	Geopolymer using waste (PSA); improves strength; eco-friendly method	Modern research; high potential for sustainable construction

III. COMPONENTS OF STABILIZATION

3.1 Soil

- Type (clay, sand, silt)
- Mineral composition
- Moisture content

3.2 Stabilizing Agents

- Cement



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- Lime
- Fly ash
- Bitumen
- Industrial waste materials

3.3 Water

- Required for chemical reactions
- Helps in compaction and workability

3.4 Equipment

- Rollers (compaction)
- Mixers
- Sprayers

IV. FACTORS AFFECTING SOIL STABILIZATION

4.1 Soil Type

Clay soils respond well to lime, while sandy soils are better stabilized with cement.

4.2 Moisture Content

Optimum moisture content is essential for proper compaction and strength gain.

4.3 Type and Quantity of Stabilizer

The performance depends on the correct dosage of stabilizing material .

4.4 Compaction

Proper compaction increases density and reduces voids.

4.5 Environmental Conditions

Temperature, rainfall, and curing conditions affect the stabilization process.

4.6 Time (Curing Period)

Strength increases with curing time due to chemical reactions.

V. STABILIZATION METHODS

5.1 Mechanical Stabilization

Mechanical stabilization improves soil properties by physical means:

- Compaction
- Soil mixing/blending
- Reinforcement (geotextiles, fibers)

5.2 Chemical Stabilization

- Lime Stabilization – reduces plasticity and swelling
- Cement Stabilization – increases strength and durability
- Fly Ash Stabilization – improves bearing capacity

5.3 Biological Stabilization

- Use of bacteria (MICP technique)
- Eco-friendly and sustainable

5.4 Thermal Stabilization

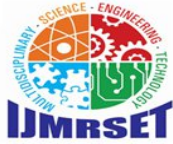
- Heating or freezing soil
- Used in special conditions

5.5 Electrical Stabilization

- Electrokinetic methods
- Used in fine-grained soils

APPLICATIONS OF SOIL STABILIZATION

- Road and highway construction



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- Airport pavements
- Foundation improvement
- Embankments and dams
- Slope protection

ADVANTAGES

- Improves soil strength and stability
- Reduces construction cost
- Enhances durability
- Utilizes waste materials

LIMITATIONS

- Not suitable for all soil types
- Requires proper design and testing
- Environmental concerns with chemicals

MODERN TRENDS AND FUTURE SCOPE

- Use of industrial waste (fly ash, plastic waste)
- Development of eco-friendly stabilizers
- Application of nanotechnology
- Smart materials and sustainable construction

Modern research focuses on reducing environmental impact while improving soil performance.

VI. CONCLUSION

Soil stabilization is a vital technique in geotechnical engineering for improving weak soil properties. Various methods such as mechanical, chemical, and biological stabilization are used depending on soil conditions and project requirements. With advancements in technology and sustainable materials, soil stabilization continues to play a crucial role in modern infrastructure development. Future research should focus on eco-friendly and cost-effective solutions to meet growing construction demands.

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